IS 11612 (2004): Code of practice for eddy current testing of non-ferrous seamless pipes and tubes [MTD 21: Non-Destructive Testing]

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*भारतीय मानक*

# अलौह जोड़ रहित पाईपों और नलियों पश्च धारा परीक्षण की अनुशंसित रीति

*( पहला पुनरीक्षण )*

*Indian Standard*

# CODE OF PRACTICE FOR EDDY CURRENT TESTING OF NON-FERROUS SEAMLESS PIPES AND TUBES

*( First Revision )*

ICS 77.040.20, 23.040.15



**BUREAU OF INDIAN STANDARDS**
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**Price Group 3**

FOREWORD

This Indian Standard (First Revision) was adopted by the Bureau of Indian Standards, after the draft finalized by the Non-destructive Testing Sectional Committee had been approved by the Metallurgical Engineering Division Council.

This standard was first published in 1984. While reviewing this standard the committee felt to revise this standard in view of the accepted current practice for eddy current testing of non-ferrous pipes and tubes.

In this revision following modifications have been made:

a) Scope has been modified;
b) Terminology clause has been modified; and
c) Clause **4.4** and **5.4** has been modified.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical value (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

*Indian Standard*

# CODE OF PRACTICE FOR EDDY CURRENT TESTING OF NON-FERROUS SEAMLESS PIPES AND TUBES

*( First Revision )*

## 1 SCOPE

This standard prescribes the methods of eddy current detection of defects in seamless pipes and tubular products of outer diameter from approximately 3.0 to 50.0 mm. This standard is applicable only to non-ferrous pipes and tubes including cupronickel of uniform cross-section and composition.

## 2 TERMINOLOGY

**2.0** For the purpose of this standard, the following definitions shall apply.

**2.1 Depth of Penetration** — For a given material and for given conditions of test coil assembly, frequency of alternating current supplied to coil etc, the magnetic field strength and consequently the intensity of induced eddy currents in the material decreases in value from the surface (close to the coil) towards the interior of the material. The depth of which the magnetic field strength or the intensity of induced eddy current has decreased to $1/e$ (or 37 percent) of its surface value is celled 'depth of penetration' where $e$ is the base of neperian logarithm. Synonymous terms are 'standard depth of penetration' and 'skin depth' (*see* Annex A).

**2.2 Eddy Current** — Electrical currents caused to flow in a conductor by the time or space variation, or both, of an applied magnetic field.

**2.3 Effective Depth of Penetration** — Though theoretically the intensity of induced currents reduced to zero at infinite depth, for practical purposes considering the test system and detection capability, the induced eddy currents in the material do reach zero value at infinite depth beyond which the test system does not 'see' the material. This depth in the material at which the induced eddy-current intensity practically reduces to zero is called 'effective depth of penetration'. In effect, the test system does not detect any defect situated beyond the effective depth of penetration in the material.

NOTE — The frequency of alternating current fed to the coil assembly shall be chosen that wall thickness of the material is less than the effective depth of penetration and the condition stipulated in **5.4** is satisfied.

**2.4 End Effect (or Edge Effect)** — The effect of the magnetic field caused by the geometric boundaries of the test specimen that makes it impractical to apply electromagnetic test methods to the associated regions of the test specimen. A large indication generally develops which masks the indication of discontinuities in this region.

**2.5 Saturation** — Magnetic saturation is needed to suppress the effect the effect of permeability variation due to ferromagnetism in cupronickel tubes. The level of saturation the tube is to be decided by trial and error method so as to get best signal to noise ratio. The saturation unit should be capable varying saturating currents. Precaution should be taken to avoid over heating of saturating coil.

## 3 PRINCIPLE OF TEST

The test is performed to passing the tube through or in the proximity of a coil(s) energized with alternating current at one or more frequencies. This alternating current induces eddy-currents to flow in the tube as a result of electromagnetic induction. The test coil detects the resultant electromagnetic flux related to these currents. The presence of discontinuities in the tube will cause change in flow of eddy-currents. Where a discontinuity is present, the eddy-current flow is impeded and changed in direction, causing, significant changes in the associated electromagnetic field.

During the passage of the tube the changes in electromagnetic response caused by the presence of discontinuities in the tube are detected by the test coil which are amplified and modified in order to actuate audio/or visual indicating device (such as a cathode ray oscilloscope/or a recorder), a mechanical marker or a combination of these.

## 4 EQUIPMENT

### 4.1 Electronic Unit

The main apparatus shall consist of a source of alternating current of a fixed or variable frequency applied to a test coil assembly, and an electronic detecting system to sense and indicate variations in the output of the coil assembly. The detecting system may include a phase selector and filter circuit. The frequency, selected for the test shall be such that the

effective depth of penetration is greater than the wall thickness of the tube under inspection. For guidance of users, a graph indicating the variation of depth of penetration with frequency of alternating current through the test coil for various non-ferrous material is given in Annex A.

### 4.2 Test Coil Assembly

One or more coils supplied with alternating current and placed in proximity to and therefore, electromagnetically coupled to the material being tested and responds to variations in these eddy-currents caused by discontinuities in the material. The coil may be either a probe coil or an encircling coil of the absolute or differential type.

### 4.3 Transport Assembly

A material transport and guiding system shall be provided if necessary, which will advance the tube at the required rate. There shall be no excessive vibration or mis-orientation of the tube and the feed speed shall be constant within ±10 percent. The transport assembly shall in no way damage the tubes being tested.

### 4.4 Filters

It is a network that transmits energy at frequencies within one or more frequency bands and attenuates energy at all other frequencies. The continuous variable HI PASS and LOW PASS filters are desired. For a given speed optimum filter setting is to be done.

### 4.5 Saturation System

Saturation unit and saturation coil is needed to inspect the (ferro magnetic) cupronickel tubes effectively. The provision to vary the saturation level should be provided. Suitable demagnetization shall be provided to demagnetize the tube to an acceptable limit, namely — less than 8 Gauss. (The value of demagnetization to be pre-decided by buyer and seller of tubes.)

### 4.6 Other Accessories

Either a recorder, an alarm or a marking system along with a sorting system shall be used along with the main equipment to keep the records of inspection for further reference as decided by buyer and seller of tubes.

## 5 TEST PROCEDURE

### 5.1 Reference Standard

**5.1.1** A reference standard free from natural defects shall be prepared from a length of tube of the same size, composition and metallurgical conditions of the tubes to be inspected.

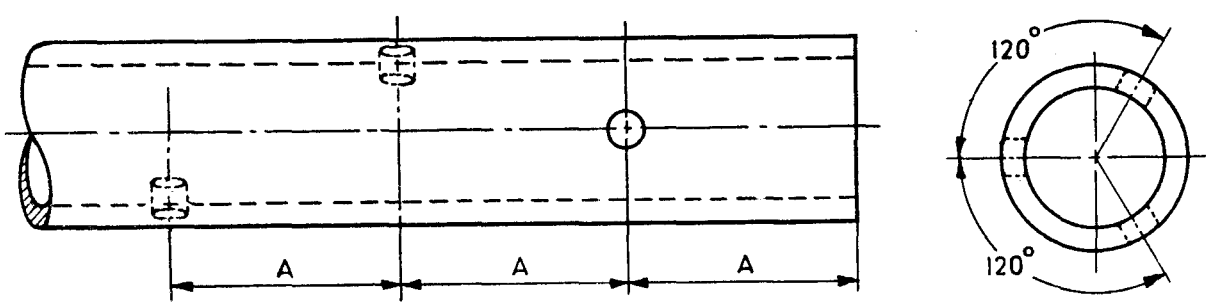
**5.1.2** The artificial discontinuities shall be introduced as follows:

a) *Drilled holes* — Three holes of the same nominal diameter shall be drilled through the wall and perpendicular to the surface of the calibration standard. The three holes shall be displaced circumferentially at 120° from one another, and sufficiently apart from each other axially and from the end of the tube to ensure that signals from each can be easily resolved and are not influenced by end effect (*see* Fig. 1).

b) The holes shall be drilled radially through the wall using a suitable drill jig that has a bushing to guide the drill, care being taken to avoid distortion of the tube and the hole while drilling. The diameter of the drilled hole shall be in accordance with Table 1 and shall not vary by more than +0.025 mm, –0.000 mm of the hole diameter specified.

Such a reference standard shall not be construed as a measure of the size of any imperfection detectable by eddy-current testing.

NOTE — The reference standard should be frequently examined for damages like scars and dents.




*A* = Space to provide signal resolution adequate for interpretation.

FIG. 1 CALIBRATION STANDARD WITH THREE HOLES

**5.1.3** The diameter of the holes may be as per the product specification and be subject to agreement between the contracting parties. Table 1 may be used as a guideline for the dimension of the reference holes.

**Table 1 Diameter of Drilled Holes**

(*Clauses* 5.1.2 *and* 5.1.3)

All dimensions in millimetres.

| Outside Diameter of Tube | | Diameter of Drilled Holes |
|---|---|---|
| Over | Up to and Including | |
| (1) | (2) | (3) |
| 3 | 6 | 0.50 |
| 6 | 19 | 0.65 |
| 19 | 25 | 0.80 |
| 25 | 32 | 0.95 |
| 32 | 38 | 1.05 |
| 38 | 44 | 1.15 |
| 44 | 50 | 1.30 |

### 5.2 End Effect

The end effect shall be determined by drilling a series of holes near one or both the ends of a special calibration tube and passing the tube through the tester to determine the distance from the tube and up to which discontinuity is detected.

When holes are made at one end only, pass the tube through the coil twice, once each with holes at the leading and trailing ends.

The end effect shall be determined only once for each size, gauge, speed and test frequency. It need not be repeated during each calibration check.

### 5.3 Surface Preparation

The surface of the tube shall be free from such metallic particles, other foreign materials and roughness that may interfere with the interpretation of the test results.

### 5.4 Temper Condition

Eddy-current testing of tubes should be conducted on tubes in drawn condition prior to final heat treatment in absence of special agreement between the supplier and the purchaser.

The tubes are either pre-straightened or made to pass in straight position while testing is performed. The automation for handling the tubes is to be decided by the purchaser and the supplier of eddy-current tester.

### 5.5 Adjustment of the Instrument

The reference standard shall be passed through or in the proximity of the test coils at the same speed and in the same manner as the tubes would be passed during inspection. The instrument settings and frequency and the speed of the test shall be optimized to consistently detect all the three reference defects, the instrument should be set to mark such detected effects. This setting of the instrument shall not be altered during testing of the lot. The alarm level and the marking mechanism shall be so set that an alarm or a mark is given each time a defect passes the test coil.

### 5.6 Mode of Testing

**5.6.1** The tubes shall be passed through or in the proximity of the test coil with speed being maintained within ±10 percent of its nominal value. Wobbling, vibrations and the mis-orientation of tube axis with respect to coil axis shall be kept minimum. Any section or length of tubing giving a defect indication equal to or greater than that produced by the reference standard shall be segregated from the material producing indication of lesser electrical magnitude.

**5.6.2** Unless otherwise specified amplitude (all phase) mode of inspection shall be used. The phase sensitive and sector mode may be used by mutual consent of tube manufacture and the user.

**5.7** The proper functioning of the equipment shall be checked:

a) at the beginning of the test,
b) every one hour during production run or after a batch of 50 tubes,
c) after finishing test, and
d) whenever malfunctioning is suspected.

If malfunctioning is confirmed all the tubes which have been tested since the last satisfactory calibration shall be retested.

## 6 LEVEL OF ACCEPTANCE

**6.1** The acceptance standard shall be based on the setting of the instrument to a sensitivity adequate to detect all the 3 artificial defects of the reference sample.

## 7 REPORT OF TEST RESULTS

**7.1** The test report shall contain the following information:

a) Component drawing reference number where applicable;
b) Specification of material, including its dimension;
c) Surface condition of the tubes;
d) Make of the instrument;
e) Description of the coil assembly, including inner diameter of test coil, method of magnetic saturation;
f) Frequency used and instrument setting;
g) Location size and extent of defects;
h) Recorder chart where available; and
j) Any unusual occurrence encountered during the test.

# ANNEX A

(*Clauses* 2.1 *and* 4.1)

## VARIATION OF DEPTH OF PENETRATION WITH FREQUENCY OF ALTERNATING CURRENT

**A-1** Figure 2 indicates the variation of depth of penetration with frequency of alternating current through the test coil for various non-ferrous metals. Figure 3 indicates the same for different type of alloys.

For theoretical estimation of depth of penetration, the following formula may be used:

$$S = 50\,292\,\sqrt{\rho/uf}$$

where

$S$ = depth of penetration in mm;

$\rho$ = resistivity of the type, being tested, in ohm-cm;

$u$ = magnetic permeability (1 for non-magnetic material); and

$f$ = frequency in hertz.

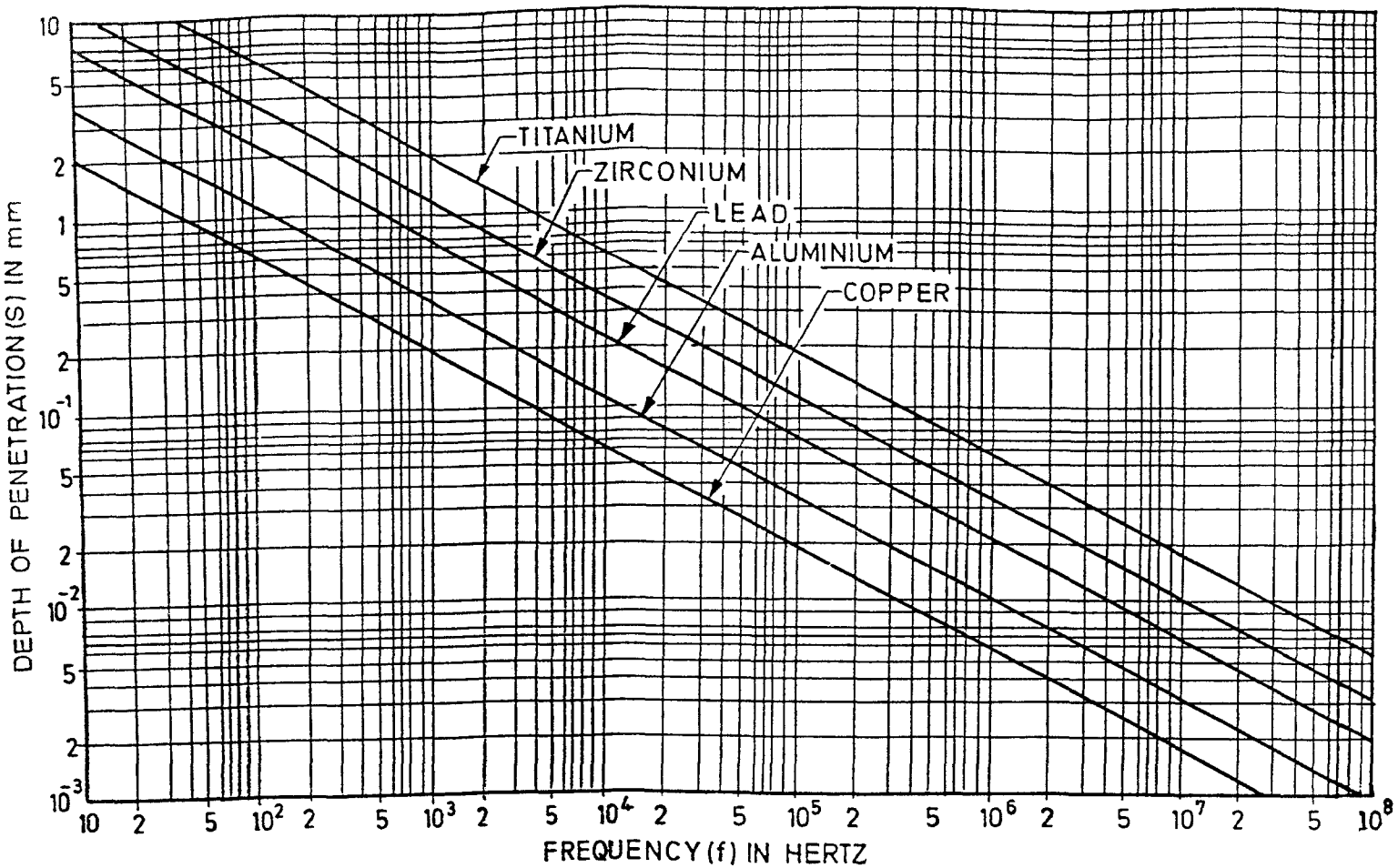



FIG. 2 VARIATION OF DEPTH OF PENETRATION WITH FREQUENCY OF ALTERNATING CURRENT THROUGH THE TEST COIL FOR VARIOUS NON-FERROUS METALS

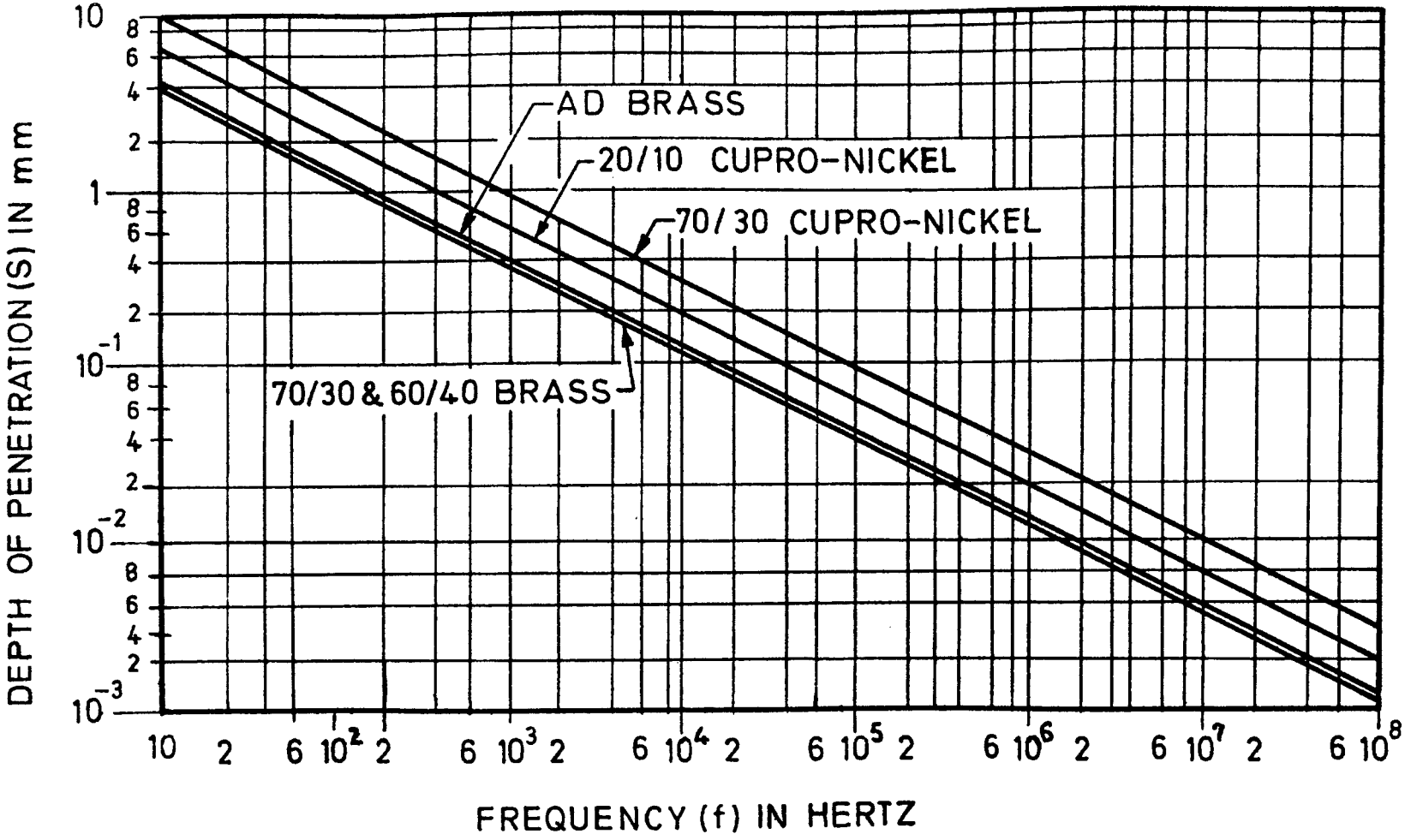



FIG. 3 VARIATION OF DEPTH OF PENETRATION WITH FREQUENCY OF ALTERNATING CURRENT THROUGH THE TEST COIL FOR VARIOUS NON-FERROUS ALLOYS

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